CARDIOVASCULAR SURGERY

Clinical and echocardiographic assessment of the Medtronic Advantage aortic valve prosthesis: the Scandinavian multicentre, prospective study

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Objective: The aim of this report is the prospective, multicentre evaluation of clinical results and haemodynamic performance of the Medtronic Advantage aortic valve prosthesis.
Methods: From April 2001 to June 2003, 166 patients (male:female 125:41; mean (SD) age 61.8 (11.8) years) received an aortic advantage valve prosthesis. Complete cumulative follow-up was 242.7 patient-years (maximum 3.2; mean 1.6 years). Postoperatively, patients underwent early (within 30 days) and 1 year transthoracic echocardiography.
Results: 30 day mortality was 2.4% (n = 4). Kaplan–Meier estimates of freedom from complications and linearised rates were as follows: 96.9 (1.6)% survival; 94.7 (1.3)% (2.06 patients/year) thrombo-embolism; 99.4 (0.6)% (0.4 patients/year) bleeding; 98.8 (0.9)% (0.8 patients/year) non-structural valve dysfunction; 98.8 (0.9)% (0.8 patients/year) reoperation. Valvular mean pressure gradients ranged from 16 (3) mm Hg for size 19 to 7 (2) mm Hg for size 27 and the corresponding effective orifice areas ranged from 1.2 (0.25) to 3.2 (0.66) cm^2. In all, left ventricular mass significantly decreased ($p<0.001$) and fractional shortening increased ($p<0.001$) from postoperative to 1 year echocardiography.
Conclusions: Haemodynamic performance and early clinical results of Medtronic advantage in the aortic position were satisfactory and comparable with those of other bileaflet valves in current clinical use.

The bileaflet valve design is the most widely implanted mechanical heart valve prosthesis. This is because of its favourable forward flow haemodynamics, ease of implantation, durability and successful clinical performance. A technical feature peculiar to all bileaflet valves is that in the opened position the two leaflets create three orifices that allow blood to flow forward. Most bileaflet valves have the central orifice smaller than the lateral ones.[1 2] It has been shown recently that a smaller central orifice causes blood turbulence that might trigger thrombogenic processes.[1 2] In an effort to reduce blood turbulence, Medtronic has created Advantage, a new bileaflet heart valve prosthesis which is characterised by a larger central orifice.[1 2] Other characteristics of this new valve includes the asymmetric butterfly hinge socket, which in conjunction with the leaflet wiping action, combines to reduce the likelihood of thrombosis in the hinge pockets.[1 2]

As all new valve models, the Advantage underwent exhaustive in vitro and in vivo testing to evaluate its flow haemodynamics and clinical outcome in the short term.[1 2] Although these laboratory and animal tests provide an adequate background for launching the valve on the market, the ultimate test is the evaluation of its performance in the human clinical setting. At present, only two studies are available in the literature reporting the haemodynamic performance of the Advantage in small groups of patients.[3 4]

This study has the dual purpose of presenting the clinical outcome in a short-term period and the haemodynamic performance of the Advantage aortic valve prosthesis, by means of echocardiography, gathered from the prospective, cooperative experience of three cardiac surgical centres in Scandinavia.

MATERIAL AND METHODS

Patient population

From April 2001 to June 2003, 166 patients underwent aortic valve replacement with Medtronic Advantage heart valve prosthesis at the three Scandinavian centres participating in the worldwide clinical assessment study on the advantage valve. The study group was made up of 125 (75.3%) men and 41 (24.7%) women with a mean (standard deviation (SD)) age of 61.8 (11.8) years and a body surface area 1.9 (0.1) m^2. Aetiology of aortic valve disease was so divided: 78 (46.9%) stenosis, 28 (16.3%) regurgitation and 60 (36.2%) stenosis and regurgitation. In all, nine (5.4%) patients had undergone previous cardiac surgery. Concomitant surgery was performed in a total of 74 (44.6%) patients. The most common procedures were coronary artery bypass grafting in 57 (34.3%) patients and replacement/repair of the ascending aorta in 13 (7.8%) patients.

Surgical technique and anticoagulation management

Surgery was performed during cardiopulmonary bypass in mild hypothermia (32°C). Myocardial protection was achieved by infusing cold blood or crystalloid cardioplegia in the aortic root and eventually retrograde through the coronary sinus or directly in the coronary ostia. In all, 123 valves were implanted in a supra-annular position, whereas 43 prostheses were placed intra-annularly.

Anticoagulation with sodium warfarin was started 24 h after valve replacement to maintain an international normalised

Abbreviations: EOA, effective orifice area; EOAI, effective orifice area index; INR, international normalised ratio; LVM, left ventricular mass; LVOT, left ventricular outflow tract; NYHA, New York Heart Association; PI_{LVOT}, performance index calculated using the left ventricular outflow tract area; PI_{TAA}, performance index calculated using the tissue annulus area

ratio (INR) level between 2.5 and 3.5. After discharge, patients' anticoagulation levels were controlled by their own doctors.

Follow-up
Enrolment of patients in the study ended June 2003. Each centre followed up its own patients, and the outcome and adverse events were entered into a dedicated database (Oracle Clinical). The follow-up was 100% complete; cumulative follow-up was 242.7 patient-years (maximum 3.2; mean 1.6 years).

Echocardiography
Echocardiograms for the assessment of functional and haemodynamic valve performances were always carried out by the same echocardiographer in each participating centre. Each patient was scheduled for a transthoracic echocardiogram within 30 days postoperatively and at 1 year.

Dimensions were measured from the standard two-dimensional and M-mode echocardiography. Doppler echocardiography was obtained from the standard acoustic windows including the suprasternal notch and the right parasternal window. The ultrasonography window from which the highest velocities were obtained was selected and used for Doppler evaluation. Flow velocity in the left ventricular outflow tract and across the valve was measured by means of pulsed and continuous wave Doppler ultrasonography, respectively. The modified Bernoulli equation was used to calculate peak and mean pressure gradients across the prosthesis.

The following parameters were collected from each patient: cardiac output, cardiac index, left ventricular ejection fraction mean and peak prosthetic valve gradients, valve effective orifice area (EOA), effective orifice area index (EOAI), performance index calculated using the tissue annulus area from prosthetic valve size (PI_{TAA}), or using the left ventricular outflow tract area (PI_{LVOT}), discharge coefficient, dimensionless obstruction index, left ventricular mass (LVM) and LVM index left ventricular fractional shortening. See appendix for definitions of echocardiographic measurements and calculations.

Statistical analysis
Outcomes were presented according to the relevant guidelines for reporting on valve-related mortality and morbidity.[5] Descriptive statistics were presented as mean (SD).

Estimated survival and freedom from event rates were calculated by the Kaplan–Meier method with a confidence limit of 95%. Linearised rates were used to describe the rate of valve-related complications and were calculated as the number of events occurring postoperatively divided by the cumulative patient-years of follow-up.

The Wilcoxon signed rank test was used to compare decrease of New York Heart Association (NYHA) functional class between preoperative and 1 year follow-up. The Kruskal–Wallis test was used to assess differences across valve sizes for each parameter at 1 year echocardiographic control. The Mann Whitney U test was used to evaluate differences in measurements across valve sizes and for each valve size over the two echocardiographic controls. A probability (p) value $\leqslant 0.05$ was considered statistically significant. Data were analysed using the StatView statistical software.

RESULTS
In all, four (2.4%) patients died within 30 days from the operation; causes of death were myocardial infarction owing to coronary artery disease in three patients and stroke in one patient.

Follow-up
Survival
Four (2.5%) patients died during follow-up. In all, two valve-related cardiac deaths, one after reoperation for a paravalvular leak and one sudden death were noticed. Two non-cardiac deaths occurred: one patient died of liver failure and one patient of cancer. Kaplan–Meier freedom from late death with and without 30 day mortality was 94.6 (2)% and 96.9 (1.6)%, respectively.

Valve-related mortality
There were two deaths: one sudden and one after reoperation. Kaplan–Meier freedom from valve-related mortality was 98.8 (0.9)% with a linearised rate of 0.8 patient/year.

Thromboembolism
A total of five patients experienced this complication, two of them within 30 days, postoperatively. Four patients had a transient ischaemic attack; at the time of the event, three patients were in atrial fibrillation and the INR was below therapeutic range in all the three patients. The remaining patient had a stroke; he was in atrial fibrillation and the INR was 1.4 when admitted to hospital. Kaplan–Meier freedom from thromboembolism was 94.7 (1.3)% with a linearised rate of 2.06 patient/year. A total of 134 patients were in sinus rhythm (mean INR 2.7) and 15 patients were in atrial fibrillation (mean INR 2.3).

Bleeding
One patient experienced gastrointestinal bleeding requiring transfusion; Kaplan–Meier freedom from bleeding was 99.4 (0.6)% with a linearised rate of 0.4 patient/year.

Non-structural dysfunction
Two patients developed a paravalvular leak; at reoperation, one patient had the valve resutured, whereas the valve was replaced in the remaining patient; one patient died at reoperation. At the end of follow-up, 98.8 (0.9)% of patients were free from non-structural dysfunction and reoperation, whereas the linearised rate for both complications was 0.8% patient/year.

No other valve-related complications were observed in any patient during the follow-up.

The weighted mean NYHA functional class of patients improved by significantly, decreasing from 2.7 (0.6) preoperatively to 1.1 (0.3) at 1 year ($p<0.001$).

Echocardiography
Of the 162 patients who entered the follow-up, 151 patients underwent both the 30 day and 1 year echocardiographic assessment of their advantage valve as by study protocol. The results reported herein are those collected in these patients. Table 1 shows the details of all parameters and their data at 1 year. In all, 11 patients were lost to 1 year echocardiographic control owing to late death (4 patients) and refusal to undergo the echocardiographic control (7 patients).

Mean gradient
Mean gradients fell gradually from 16 (3) mm Hg for size 19 mm to 7 (2) and 8 (2) mm Hg for size 27 and 29 mm at 1 year, respectively ($p<0.001$; table 1). A decrease in mean gradient was noticed from postoperative to the 1 year control; the overall trend across valve sizes ($p = 0.02$) and for 23 ($p = 0.02$) and 27 mm ($p = 0.02$) reached statistical significance (fig 1).

Table 1 Transthoracic Doppler echocardiographic data of Medtronic Advantage aortic valve at 1 year follow-up

Parameter	Valve size 19	21	23	25	27	29	p Value
Patients, n	7	36	45	40	16	7	
CO (l/min)	5.5 (1.5)	6.4 (2.4)	6.6 (2.4)	7.2 (2.8)	6.8 (1.3)	8.7 (2)	0.02
CI (l/min/m^2)	3.1 (0.9)	3.5 (1.3)	3.4 (1.2)	3.4 (1.2)	3.4 (0.6)	4.2 (1)	0.25
HR (bpm)	73 (6)	67 (11)	64 (11)	64 (9)	60 (10)	73 (13)	0.07
LVEF (%)	58 (10)	61 (6)	60 (5)	57 (7)	58 (6)	54 (11)	0.34
PG (mm Hg)	28 (8)	23 (8)	20 (6)	16 (6)	13 (4)	14 (2)	<0.0001
MG (mm Hg)	16 (3)	13 (5)	11 (4)	9 (3)	7 (2)	8 (2)	<0.0001
EOA (cm^2)	1.2 (0.25)	1.66 (0.41)	2.08 (0.5)	2.4 (0.57)	2.91 (0.47)	3.22 (0.66)	<0.0001
EOAI (cm^2/m^2)	0.68 (0.16)	0.91 (0.24)	1.07 (0.27)	1.15 (0.27)	1.45 (0.24)	1.56 (0.35)	<0.0001
$PI_{(TAA)}$	0.29 (0.06)	0.34 (0.08)	0.36 (0.08)	0.36 (0.08)	0.39 (0.06)	0.38 (0.07)	0.01
$PI_{(LVOT)}$	0.42 (0.08)	0.48 (0.1)	0.5 (0.11)	0.51 (0.11)	0.52 (0.08)	0.48 (0.07)	0.13
DC	0.71 (0.15)	0.78 (0.19)	0.78 (0.19)	0.75 (0.18)	0.75 (0.12)	0.71 (0.14)	0.89
DOI	0.43 (0.08)	0.48 (0.1)	0.5 (0.1)	0.52 (0.12)	0.52 (0.08)	0.48 (0.07)	0.11
LVM (g)	230 (77)	181 (44)	205 (58)	255 (91)	252 (43)	328 (150)	<0.0001
LVMI (g/m^2)	129 (40)	99 (23)	105 (28)	123 (40)	126 (22)	153 (59)	0.002
FS (%)	37 (15)	40 (9)	38 (9)	34 (10)	35 (9)	26 (4)	0.009

Values are expressed as mean (SD).
CI, cardiac index; CO, cardiac output; DC, discharge coefficient; DOI, dimensionless obstruction index; EOA, effective orifice area; EOAI, effective orifice area index; FS, fractional shortening; HR, heart rate; LVM, left ventricular mass; LVMI, left ventricular mass index; MG, mean gradient; PG, peak gradient; PI, performance index; PI_{LVOT}, performance index calculated using the left ventricular outflow tract area; PI_{TAA}, performance index calculated using the tissue annulus area.

Effective orifice area
At 1 year, the valve EOA was satisfactory for all sizes. There was not a significant increase in EOA across all valve sizes from postoperative to 1 year ($p = 0.7$).

Effective orifice area index
The EOAI to body mass was adequate ($\geqslant 0.85$) in all valve sizes but 19 mm.[6] There was no significant increase of indexed areas across valve sizes from postoperative to 1 year echocardiogram ($p = 0.9$).

Performance indices
Similar ranges of PI_{TAA} and PI_{LVOT} were observed across valve sizes between the two echocardiographic controls: PI_{TAA} ($p = 0.5$), PI_{LVOT} ($p = 0.7$).

Discharge coefficient
There was no statistical significant difference between early and 1 year control for the whole cohort ($p = 0.5$).

Dimensionless obstruction index
The difference across valve sizes between the two observational times was not significant ($p = 0.8$).

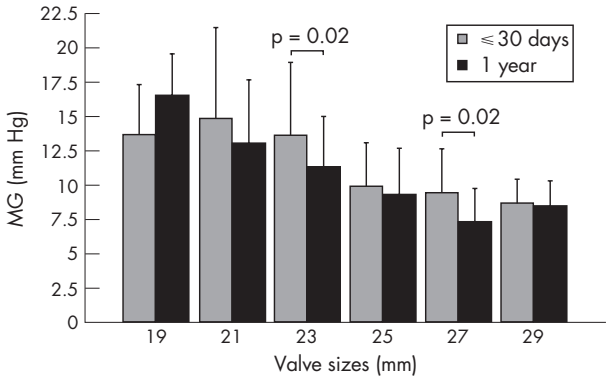

Figure 1 Mean transvalvular gradients (MG) calculated postoperatively and at 1 year. An overall significant decrease is noticed across valve sizes ($p = 0.02$) and for sizes 23 and 27 mm ($p = 0.02$) over the two observational times.

Left ventricular mass
A significant decrease of LVM across postoperative to 1 year control ($p<0.001$) was observed for the cohort of patients with valve sizes 21 to 29 mm. LVM dropped significantly in patients with valve sizes 21, 23 and 25 mm, whereas it did not change or reach statistical significance in patients with size 19, 27 and 29 mm.

Left ventricular mass index
As for the previous parameter, the body indexed-LVM showed a significant decrease at 1 year. This variation was statistically significant ($p<0.001$) for the whole cohort as well as for sizes 21–27 mm (fig 2).

Fractional shortening
Left ventricular fractional shortening increased from post-operative time to 1 year. The variation was statistically significant for the whole cohort ($p<0.001$) as well as for sizes 21, 23 and 27 mm. (table 1 and fig 3).

DISCUSSION
This prospective, three-centre study is the first to report on the haemodynamic performance of the Medtronic Advantage aortic valve prosthesis in a large population of patients.[3 4] Moreover, all the echocardiographic parameters of the valve performance and left ventricular remodelling over time are presented.

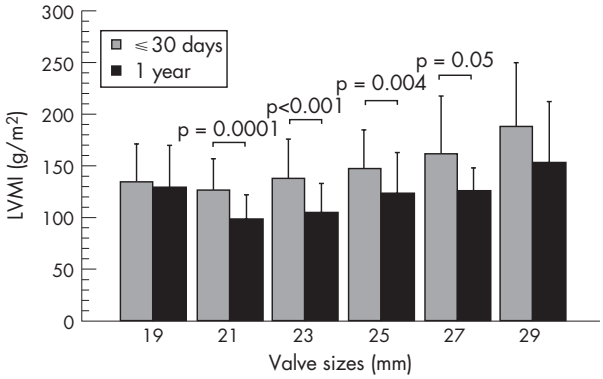

Figure 2 Left ventricular mass index (LVMI) calculated postoperatively and at 1 year. Across all valve sizes, there is an overall significant decrease ($p<0.001$) as well as for sizes 21 to 27 mm.

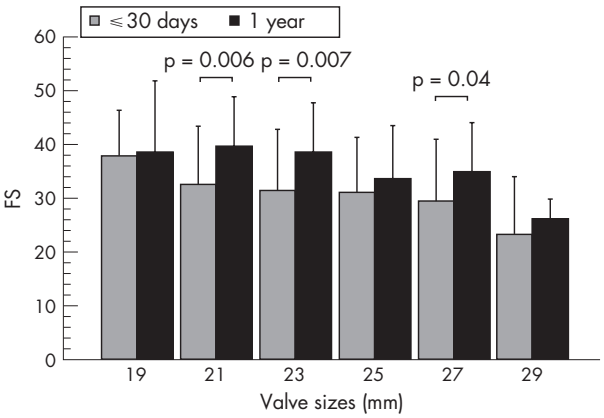

Figure 3 Fractional shortening (FS) calculated postoperatively and at 1 year. Across all valve sizes, there is an overall significant increase ($p<0.001$) as well as for sizes 21, 23 and 27 mm.

With regard to transvalvular mean gradients, larger valve sizes exhibited lower gradients. Furthermore, there was a decrease of mean gradients from postoperative to 1 year echo control that reached statistical significance for the 23 and 27 mm valves. The Advantage valve mean gradients at 1 year are in line with those reported by Chafizadeh for the St Jude Medical aortic standard valve[7] and with the mean gradients calculated by Chambers *et al*[8] and Karpuz *et al*[9] on the On-X and ATS aortic valves, respectively.

EOAs were satisfactory for all sizes at 1 year and confirmed those reported by Koertke *et al*[3] in their initial experience with the Advantage valve in a much smaller population of patients. Our results were also comparable with the outcomes reported by other authors on St Jude standard and HP (St Jude Medical, Minneapolis, Minnesota, USA), CarboMedics Top Hat (CarboMedics, Austin, Texas, USA), ATS (ATS Medical, Plymouth, Minnesota, USA) and On-X (MCRI, Austin, Texas, USA) valves.[7–12] On the other hand, the Advantage valve areas were slightly smaller than those of the St Jude Regent.[13 14] However, the Regent model was specially designed with an enlarged geometric valve area for implantation in the small aortic annulus, whereas the Advantage valve has a standard annulus design.

Indexed effective valve orifice areas were adequate. At 1 year, sizes 21–29 mm exhibited indexes >0.85 which is the cut-off point value suggested by Pibarot and Dumesnil[6] to define the patient/prosthesis mismatch. Despite satisfactory valve areas, patients with 19 mm Advantage had a moderate prosthesis/patient mismatch exhibiting a mean indexed-EOA of 0.68.

The PI_{TAA} ranged from 0.29 for 19 mm to 0.39 for 27 mm valves at 1 year. These values were lower than those found by Koertke *et al*[3] in a smaller population of patients with Advantage aortic valves. This is because the EOAs calculated in the Koertke *et al*'s report were slightly larger than those of the present series. The same range of values as in Koertke *et al*'s series were calculated by Chambers *et al* for the On-X aortic valve.[8]

The PI_{LVOT} ranged from 0.42 of 19 mm up to 0.51 of 23 and 27 mm valves, indicating that these two valve sizes make the best use of the left ventricular outflow tract (LVOT) area. This is similar to the PI_{LVOT} of CarboMedics Reduced and better than Medtronic-Hall in a small series of patients reported by the same institution that described the left outflow tract utilisation index.[15 16]

In our study, discharge coefficients varied from 0.62 of 19 mm to 0.78 of 21 and 23 mm valves at 1 year, showing these two latter sizes make a better use of the valvular geometric orifice area. These values were quite similar to those reported by Koertke *et al*[3] for the Advantage aortic valve; whereas they were slightly higher than the discharge coefficients calculated by Karpuz *et al*[9] in a series of patients with ATS aortic valves.

The dimensionless obstruction index, also known as VTI ratio in another study,[3] is independent of cardiac output and, thus, provides a sensitive indicator for prosthetic haemodynamic performance. The use of this index avoids any influence of inaccuracies in the LVOT diameter measurement for EOA calculations, and hence provides a more reliable parameter for prosthesis function. In our experience, the dimensionless obstruction index ranged around 0.50 for all sizes but 19 mm which had an index of 0.43 at 1 year. These results were in line with Koertke's Advantage series and with values obtained with other prostheses.[3 17]

All parameters of left ventricular remodelling (ie, LVM, index and fractional shortening) improved after aortic valve replacement with Advantage. These results were consistent with those reported by Guenzinger *et al*,[4] who reported a 18.4% regression of LVM across all valve sizes 1 year after advantage aortic valve implantation. In our series left ventricular mass and index decreased significantly for sizes 21 to 27 over 1 year. At the same time, the fractional shortening increased over time, reaching statistical significance for 21, 23 and 27 mm valves. These findings support the satisfactory haemodynamic performance of the prosthetic valve showing a real benefit over time for patients with the Advantage in the aortic position. At the same time, there was a marked improvement of the patients' clinical condition at 1 year, as shown by the significant reduction of mean NYHA functional class from preoperative time.

From the overall assessment of the haemodynamic performance of the Advantage aortic valve, it seems that the sizes 21 to 29 mm have produced better results, with only the 19 mm valve not being up to the same degree of performance as the other valve sizes. Nonetheless, several facts have to be kept in mind before drawing any conclusion on the haemodynamics of the 19 mm Advantage valve: first, this is the first study ever to report on haemodynamic data of the 19 mm valve and, second, the group of patients with the 19 mm valve was the smallest, being made up of seven patients only. Moreover, there were no fatal events like sudden death occurring in these patients during the follow-up despite a moderate patient/prosthesis mismatch. Therefore, haemodynamics of the 19 mm valve should be assessed in a much larger group of patients before reaching any conclusion on the real benefits after implantation of this size valve.

On clinical grounds, early follow-up results with the Advantage aortic valve were satisfactory. Kaplan–Meier estimates of survival and freedom from complications were good. Linearised rates of complications encountered during the follow-up were low and within the expected values for a promising bileaflet valve. Moreover, these results are comparable with those of other long-established bileaflet valves at their early stage of follow-up.[18–20] In this study, no patients presented with intermittent reduced excursion of one of the valve leaflets as reported in the brief communication from the Munich Heart Centre.[21]

Study limitations were that 26% of the valves were implanted in the intra-annular position. Theoretically, this might reduce valve performance because the orifice available for blood flow is reduced by the prosthetic ring sewing cuff. Nonetheless, the two subgroups (intra-annular and supra-annular) had similar mean valve size (24 mm) and haemodynamic performances. Furthermore, the technique of prosthetic valve implantation was always left to the surgeons' preference as in most multicentre studies.

Another limitation is that Doppler may underestimate prosthetic valve areas owing to transvalvular localised high velocities in bileaflet valves, as reported with the St Jude valve.[22 23] On the one hand, the design of Advantage is characterised by a larger central orifice which should reduce high velocities across the valve, improving the accuracy of Doppler derived measurements; on the other hand there might be some disturbed flow in the central orifice area as observed by Shandas *et al*[24] in bileaflet heart valves.

In conclusion, the Medtronic Advantage valve prosthesis in the aortic position has a satisfactory haemodynamic performance. All haemodynamic parameters assessed yielded good results that are comparable with those of bileaflet valves of long-established clinical use. Results of the early follow-up were within the expected outcome for a bileaflet valve. Advantage is a valid option when aortic valve replacement with a bileaflet mechanical valve is contemplated. Nonetheless, a longer follow-up in a larger population of patients is mandatory to confirm these positive early results.

APPENDIX

Echocardiographic measurements and calculations

All of the following parameters were collected from each patient:

Cardiac output (CO) = Stroke Volume × heart rate/1000. Stroke volume (SV) = CSA × VTI_{LVOT}, CSA is the subvalvular cross-sectional area in cm^2 calculated by measuring LVOT in cm as the distance between the junction of the prosthetic sewing ring anteriorly and the junction of the sewing ring and the anterior mitral leaflet posteriorly, according to the formula, CSA = $(LVOT_{diam})^2 \times 0.785$. VTI_{LVOT} is the velocity time integral from the left ventricular outflow tract (LVOT).

Cardiac Index (CI) = Cardiac output/body surface area.

Peak gradient (PG) = 4 $(V_2^2 - V_1^2)$ where V_2 is prosthetic peak velocity in m/s measured with continuous-wave Doppler and V_1 is peak velocity proximal to the valve in m/s, measured by pulsed-wave Doppler.

Mean gradient (MG) was calculated by the analysis software of the ultrasound system according to the formula $MG = MG_{V2} - MG_{V1}$, where MG_{V2} is the mean pressure gradient across the prosthesis and MG_{V1} is the mean pressure gradient in the LVOT.

The effective orifice area (EOA) is an index of how well a valve design utilises its geometric orifice area. It was calculated with the continuity equation by the velocity time integral method. EOA = CSA (VTI_{LOVT}/VTI_{Ao}); VTI_{Ao} is the velocity time integral across the prosthetic valve.

EOAI is a measure of how well the EOA of the valve matches the body surface area (BSA). It is calculated as EOAI = EOA/BSA. This index was used to detect mismatch between valve size and body surface area. According to Pibarot and Dumesnil, it would seem that an indexed prosthetic valve area of approximately 0.85 cm^2/m^2 would be adequate to minimise the postoperative gradient.[13]

The performance index (PI) is a measure of how effectively the external dimension of the valve is used to provide forward flow, normalised to the valve size. It is defined as PI_{TAA} = EOA/tissue annulus area, where the tissue annulus area is calculated from the prosthetic valve size (eg, for a 21 mm valve, TAA = π $(2.1\ cm)^2/4$). Most articles provide PI_{TA}, making possible the comparison with other valve types. Alternatively, the PI can be calculated as $PI_{LVOT} = EOA/CSA_{LVOT}$, according to our previous study,[14] where CSA_{LVOT} is the cross-sectional area of the left ventricular outflow tract calculated as for the EOA. The PI_{LVOT} provides information on the extent of utilisation of the aortic annulus area by the valve prosthesis.

The dimensionless obstruction index (DOI) provides the systolic performance of aortic valve prostheses and it is calculated by just relating the subvalvular to the valvular velocity time integrals according to the following formula: $DOI = VTI_{LVOT}/VTI_{VALV}$. This parameter is also known as VTI ratio.[4]

The discharge coefficient (DC) is a measure of how effectively the valve uses its nominal flow area and it is calculated as follows DC = EOA/GOA, where GOA is the geometric orifice area, as provided by the manufacturer.

Left ventricular mass (LVM) = $0.83 \times [(LVID_d + IVS_d + PWT_d)^3 - (LVID_d)^3] + 0.6$ g, where $LVID_d$, left ventricular internal dimension at end-diastole, in cm; IVS_d, interventricular septal thickness at end-diastole, in cm; PWT_d, posterior wall thickness at end-diastole, in cm. This formula for left ventricular mass is based on the volume-corrected ASE-cube method.[25]

Left ventricular mass index (LVMI) is the left ventricular mass index normalised for the body size, as left ventricular mass index = left ventricular mass/body surface area.

Fractional shortening (FS) = (EDD − ESD)/EDD ×100, where EDD is left ventricular diameter at end-diastole; ESD is left ventricular diameter at end-systole.

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IMAGES IN CARDIOLOGY

64 multidetector CT in patent foramen ovale

A 47-year-old woman was referred for a coronary CT angiography (64-slice scanner, Toshiba Aquilion, Tustin, California, USA). Retrospective ECG-gated datasets were acquired (collimation, 64×0.5 mm; table feed per rotation, 7.2 mm; rotation, 400 ms; tube voltage, 120 kV; and tube current, 500 mA). Using a segmented image reconstruction algorithm, a temporal resolution of <100 ms was achieved. Before scan, the heart rate was lowered to 65 bpm by 50 mg oral metoprolol. Contrast enhancement was achieved with 65 ml of Iohexol (Omnipaque 350 mg/ml, Amersham Health, Cork, Ireland) injected at 5 ml/s, followed by an injection of 50 ml of saline at 5 ml/s. Scanning initiation was triggered automatically at the threshold of 180 Hounsfield Units in the descending aorta. Using this technique, the right heart was washed out of contrast by saline chaser. This provides enough contrast to demonstrate small shunt across the interatrial septum. Presented images show a small patent foramen ovale with the jet of contrast moving from the left to the right atrium.

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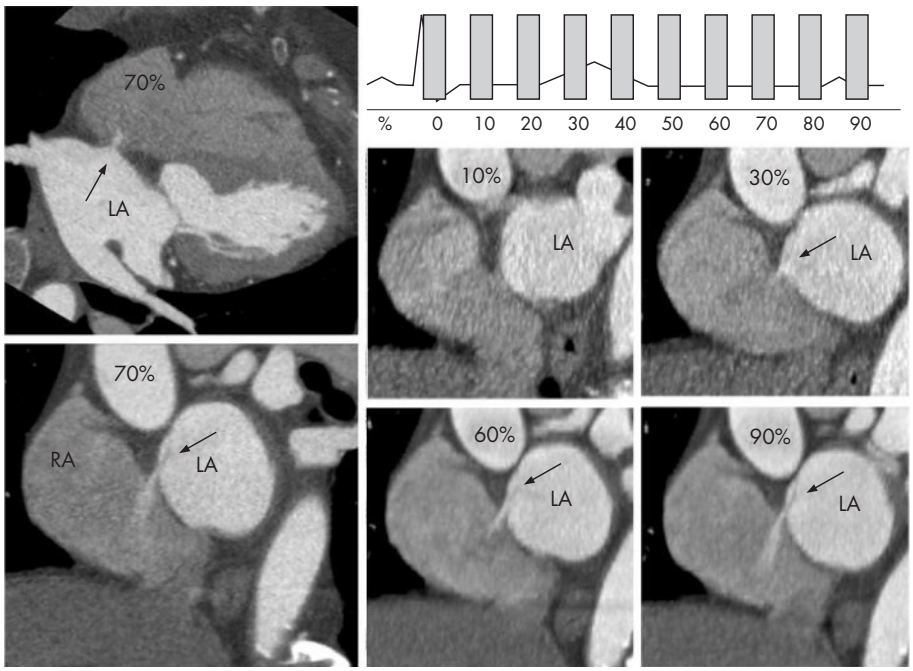

Long- and short-axis images through the interatrial septum show a small patent foramen ovale (arrows) with the jet of contrast from the left atrium (LA) to the right atrium (RA). The right heart is less dense due to washout of contrast by saline chaser. Cardiac images are obtained on the basis of relative timing intervals in steps of 10% of the R-R interval in cardiac cycle. The centre of reconstruction is placed at the relative point as shown in the diagram (top right). On the left side, high-resolution long- and short-axis views are reformatted from diastolic datasets centred at 70% of the R-R interval, with a slice thickness of 0.5 mm and increments of 0.3 mm. On the right, short-axis cine frames (2 mm thickness) from collected data at 10%, 30%, 60% and 90% intervals are shown.